DOCUMENT RESUME

ED 469 620 SE 066 754

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TITLE	Placing the History and the Philosophy of Science on Teacher Education.
PUB DATE	2002-07-00
NOTE	12p.; In: Rethinking Science and Technology Education To Meet the Demands of Future Generations in a Changing World. International Organization for Science and Technology Education (IOSTE) Symposium Proceedings (10th, Foz do Iguacu, Parana, Brazil, July 28-August 2, 2002). Volumes I [and] II; see SE 066 752. Financial support provided by FCT/Portugal.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	EDRS Price MF01/PC01 Plus Postage.
DESCRIPTORS	Chemistry; *Educational Strategies; *Epistemology; Foreign Countries; *Inservice Teacher Education; *Science Instruction; *Science and Society; Scientific Principles; Secondary Education
IDENTIFIERS	Portugal

ABSTRACT

Recent research indicated that teachers conceive and orient their teaching depending (among others things) on their conceptions about both the nature of science and the construction of the scientific knowledge. This is an important educational issue because the image generally held by students sees science simply as a rhetoric of conclusions. Science teaching strategies designed in line with the principles of the "new philosophy of science," e.g. emphasizing the context of discovery of scientific ideas (and not simply the context of justification of those ideas), methodological pluralism and the human and social side of science (STS relationships), are usually ignored. Part of the problem lies in inadequate teacher education strategies. Thus the aim of the study was to design, to develop and to evaluate an innovative teacher education program exploring the History and the Philosophy of Science (HPS) in order to improve the teaching and learning of mass conservation in chemical reactions, a key curricular theme in Portuguese secondary teaching and also a relevant historical and cultural topic of study. The main hypothesis was that it is possible to develop in-service teacher education strategies based on the HPS to promote adequate epistemological perspectives of science teachers. The research design followed was organized in three interrelated steps: a naturalistic phase (over 40 hours of teaching of two secondary teachers were video recorded and analyzed); a second phase concerning the teacher education program itself exploring action-research strategies and involving the design of new teaching plans and the construction of new didactic materials; the third phase in which the new teaching strategies were then implemented by the two teachers. Evidences of the evolution of the epistemological perspectives underlying teachers' practices from the first to the third phase are presented together with examples of the use of the HPS in the three methodological categories of analysis: scientific methodology, dynamics of the construction of scientific knowledge and the human and social face of science. The results of a triangular evaluation of the program (external observer, students and teachers self-evaluation) is also presented. We can conclude that the teacher education program developed exploring HPS was able to improve the teaching of the chosen topic, in particular making the students more aware of images of science congruent with the principles of the "new philosophy of

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science." (Contains 27 references.) (Author/YDS)

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PLACING THE HISTORY AND THE PHILOSOPHY OF SCIENCE ON TEACHER EDUCATION

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Abstract

Recent research indicates that teachers conceive and orient his/her teaching depending (among others things) on his/her conceptions about both the nature of science and the construction of the scientific knowledge. This is an important educational issue because the image of science that is generally held by students consider science simply as a rhetoric of conclusions. Science teaching strategies designed in line with the principles of the "new philosophy of science", e.g. emphasising the context of discovery of scientific ideas (and not simply the context of justification of those ideas), methodological pluralism and the human and social side of science (STS relationships), are usually ignored. Part of the problem lies in inadequated teacher education strategies. Thus the aim of this study was to design, to develop and to evaluate an innovative teacher education program exploring the History and the Philosophy of Science (HPS) in order to improve the teaching and learning of mass conservation in chemical reactions, a key curricular theme in Portuguese secondary teaching and also a relevant historical and cultural topic of study. The main hypothesis was that it is possible to develop in –service teacher education strategies based on the HPS to promote adequated epistemological perspectives of science teachers.

The research design followed was organised in three interrelated steps: a naturalistic phase (over 40 hours of teaching of two secondary teachers were videorecorded and analysed); a second phase concerning the teacher education program itself exploring action-research strategies and involving the design of new teaching plans and the construction of new didactic materials.; the third phase in which the new teaching strategies were then implemented by the two teachers.

Evidences of the evolution of the epistemological perspectives underlying teachers' practices from the first to the third phase are presented together with examples of the use of the HPS in the three methodological categories of analysis: scientific methodology, dynamics of the construction of scientific knowledge and the human and social face of science. The results of a triangular evaluation of the program (external observer, students and teachers self-evaluation) is also presented. We can conclude that the teacher education program developed exploring HPS was able to improve the teaching of the chosen topic, in particular making the students more aware of images of science congruent with the principles of the "new philosophy of science".

Introduction

Educational innovation can only really succeed if it also involves professional development and teacher empowerment. This implies a new way to look at teacher education. We now have some new general orientations to guide teacher education (Schon 1987; Zeichner 1993).What is still missing are systemic research approaches to teacher education in order to improve teachers' personal and professional growth. Teachers need to reflect more and better on their own practices and this (hopefully) will have a positive influence on their classroom strategies. It means that we need educational research strategies that will help classroom teachers to promote effective and conscious changes in their teaching.

The more consensual position indicates that each teacher conceives and orients his/her teaching depending on his/her conceptions of the nature of science and scientific knowledge, his/her professional experience, on his/her interpretation of curriculum, on the way he/she conceives education in particular the more general goals of science education.

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As Gallagher (1991) said, "secondary teachers' knowledge about the nature of science is important because they play a key role in forming the image of science that is held by the general public", and he asks "what do teachers understand about the nature of science, and how does this knowledge influence their teaching?"

Many research studies point to a strong link between teachers' conceptions and their practices (Pomeroy 1993; Lederman 1986), others consider some influences and a selected collection of situational variables (Brichouse & Bodner 1992; Lederman 1992).

Among teachers' images of science, some prevail over others, namely positivists', empiricists' and inductivists' perspectives (Aguirre 1990; Hodson 1985, 1993; Praia & Cachapuz 1994, 1998) and science is viewed exclusively as a definitive well-established body of knowledge. The understanding of scientific principles and relationships received far less attention than terminology; teachers devoted no time to the discussion of matters related to the nature of science, such as how the knowledge included in the curriculum was formulated or the process by which scientists validate knowledge, teachers emphasised the objectivity of scientific knowledge and they based the objective aspect on scientists' use of the scientific method; teachers frequently fail to point out obvious connections between classwork and the world outside the school (Gallagher 1991).

Gallagher (1991) and Matthews (1990) attribute responsibility for this to the fact that teachers have had no formal education in the history, philosophy and sociology of science.

Despite some well known dissimilarities between contemporary epistemologies about scientific construction and its structure, scientific philosophers, particularly Khun, Lakatos, Toulmin ...converge on a coherent image of science with important implications for science education (Cleminson 1990, Duschl & Guitomer 1991, Hodson 1985, 1996, Gil-Pérez 1996, Duschl 1995...). These arguments known as New Philosophy of Science (NPS) may be summed up in the following way: 1- Scientific knowledge cannot suggest an absolute truth, it has temporary status and errors must be an object of reflection; 2- Scientific discoveries have context and structure and the history of science helps us to understand those aspects; 3- Scientists are part of the very world they investigate and they must constantly submit their results to the certification of a scientific community; 4- There is no unique and singular method of producing scientific knowledge but a context-dependent methodological pluralism; 5- Observation does not exist apart from a theory that orientates and gives meaning to it. Scientific theories interpret and explain the world tentatively; and 6- Science is not objective (in the positivist sense), impersonal and problem-free, but it is closely related to society and technology.

We know that the history and philosophy of science has for many years been absent both from science curricula and, in particular, from science teacher education (Matthews 1990, Acevedo Díaz 1996, Pomeroy 1993...). During the 80's and early 90's the consideration of the inclusion of philosophical aspects in science teaching education began to increase and relate the philosophy of science to science teaching and learning.

From another point of view, as we mentioned earlier, educational research has not achieved relevant changes in classroom practices. Teaching practice is mainly guided by pedagogical preoccupations and the images of science and scientific knowledge in the classroom do not match with the NPS principles. These ideas led us to the problem of what kind of innovative strategies of teacher education should be considered in order to promote effective changes in teachers' usual classroom practices. Thus a major challenge for us is how to design and to develop effective science teacher education so that teachers may understand the importance of the inclusion of the philosophy of science in their science teaching.

There are two main aspects related to the NPS worth of attention. They are the consideration of the social construction of science and scientific knowledge and the associated technological development (STS perspectives (Matthews 1994)) and the importance of the inclusion of the history of science in science teaching. In practical terms we need to improve conditions which will enable teachers to analyse their teaching after a guided reflection on a previously selected theme of the curriculum. A possible strategy is to involve teachers in cooperative action research studies designed in order to conceive and explore concrete curricular strategies based on the history and philosophy of science (Monk & Osborne 1997) and also to analyse and discuss the

way they may implement them in the classroom.

Mass conservation in chemical reactions: an epistemologically relevant theme

As referred to by Paixão (1999) "mass conservation in chemical reactions" was selected as a relevant theme because it has usually been viewed from a poor perspective and because of this, it has been a point of crystallisation of an exclusivist form of academic knowledge; students only resolve "exercises" (non problematic questions) of equation balancing and stoichiometric aspects, and even when they do them, it does not follow that they understand what they have done.

Classroom practices and textbooks have a particular incidence of an empiricist point of view (as far as this theme is concerned) which implies the absence of current perspectives on the contemporary principles of the New Philosophy of Science. For example, Experimental Work (EW) developed in classrooms (practical work) is very far from those principles. Most of the time the practical work proposed on the theme of mass conservation follow a confirmatory epistemological perspective involving the 'classical' chemical reaction of precipitation of the lead iodide by reaction between potassium iodide and lead nitrate. On the other hand, we must consider the academic interest of the theme: it is the pre-requisite for all and subsequent understanding of chemistry and it has a central position in the curriculum of basic studies. In fact, the understanding of the mass conservation principle, and also the understanding and knowledge of the general theory of chemical reactions, is indispensable for the understanding of the properties and the transformation of substances. There are many research studies that point out the existence of students alternative conceptions about this theme (Hesse & Anderson 1992, Yarroch 1985, Ben-Zvi et al. 1987...)

From the epistemological point of view, the study of the controversies that followed the interpretation of one of the most common chemical reactions, i.e. combustion, and the establishment of the general theory of chemical reactions, the mass conservation principle (later an empirical law), which guided Lavoisier in the establishment of his theory, cannot be underestimated. It is also a historically and culturally strong theme due to the correspondence of a period in the history of mankind and in the history of science with many special important social, economical, political and scientific implications. After the commemoration of the 200 years since Lavoisier's death, the available literature about that period of chemical history increases quantitatively and qualitatively (Bensaude Vincent & Stengers 1996). The theme is also important in a social and technologically up-to-date and foreseen future context – thermal power stations; incineration; recycling...

Teachers cannot ignore all those questions about the way scientific knowledge grows, and they must give students an image of that difficult and contextualized construction.

There are, in fact, many epistemological elements that contribute to a more consistent image of science, like scientific controversy, scientific community and societies, technologies associated with science, publications, communications and scientific correspondence... acceptance or non acceptance of a new theory... social, economical and political implications which, as was the case in a period such as the French Revolution, influenced the status of chemistry as a modern science. That is a cultural view of science very different from the instrumental image transmitted by teachers in science classrooms.

Hypothesis and aims

The main hypothesis that guided the study was that it is possible to develop in-service teacher education strategies in order to promote teachers' professional and personal growth, using the History and Philosophy of Science (HPS) framework in the teaching of science curriculum themes. This, in turn, results in a substantial empowerment in professional fulfilment and in the suitable images of science transmitted to the students. The assumption is that students' learning increases in the same desirable direction.

The aim of the study was to develop a Teacher Education Program (TEP) in order to improve both the epistemological perspectives of teachers and their teaching strategies of the theme "mass conservation in chemical reactions" (low secondary school) using the HPS framework.

Methodology and procedures

This research is included in a case study methodology in the perspective indicated by Yin (1987, 14): "The case study allows an investigation to retain the holistic and meaningful characteristics of real-life events" and "are the preferred strategy when "how" and "why" questions are being posed". The results from the research are concrete aspects related to each presented case and they can be used to confront them with others in similar contexts and to stimulate continuing research in the same direction. This is more a question of transferability than a question of generalisation.

The study was developed in three main related phases.

The general purpose of the first phase of the research was to elucidate the teachers´epistemological perspectives as revealed by their practices. The question that guided the 1st phase was to investigate the congruence (if any) between the theoretical framework and the nature of classroom practices of teachers. Beyond this general purpose, the effective value of that first phase in the whole study, was to elucidate the main difficulties which teachers faced in their practices, to give us some orientations for the elaboration of alternative teaching strategies and to obtain videorecorded materials to be explored in the individual teacher education phase (2 th phase). These videorecorded materials gave the opportunity for participant teachers to become aware of the need to develop the epistemological dimension of the understanding of science teaching and learning and to allow them to assess the evolution of their practice. Thus an awareness of the progress made concerning the images of science and scientific knowledge held before and after the participation in subsequent phases of the study. With these objectives in mind the study was conducted according to a naturalistic approach. Four in-service Physics and Chemistry teachers, all of whom were female, participated in the study during the first phase. The participants were permanent members of the staff of four different Portuguese (low) secondary schools. The academic background and the professional experience of the participants were diversified. We videorecorded over 40 hours of actual teaching, on the selected theme. The written protocols were then analysed to identify teacher´s epistemological conceptions (oral discourse and teaching activities implemented). It was simultaneously a descriptive and a critical interpretative process of data analysis, guided by a theoretical framework instrument (Figure 1). This was the instrument of analysis of classroom practices.

Epistemological Categories	Analysis Dimensions	Teaching Practice Indicators(examples)
I - Scientific Methodology	A - Methodological pluralism	Explicit references to some episodes of the HS and/or current aspects of scientific investigation with relevance to different scientists' working methods. Discussion of students' ways of working with clarification of the means of selecting experimental procedures and their adequacy and/or limitation (not recipes).
	B - Theory / Observation / Experiment relations	Theoretical considerations before observation and experiments. Initial problematic questions and predictions. Critical report of the experimental work guided by problematic questions and including critical assessment of the results
II - The dynamics of Scientific knowledge construction	C - Scientific discovery Context and structure	Activities exploring historical controversies in the establishment of a given scientific theory (i.e. texts and related questions)
	D - Error /Truth Dynamics	Intentional evaluation and exploration of students' errors. Identification of misconceptions. Discussion of discrepant experimental work results.

III - The human and social side of science	E - Images of scientists and of the scientific community	Explicit references to the human side of scientists. Opportunities for the students to express their own ideas and confront them with their colleagues' ideas and/or with the current scientific version.
	F - STS interrelations	To begin with a social or a technological problem. To promote debates about science related questions, showing the relation between science and technology, ethical or environmental questions, with the opportunity for students to express their own ideas.

Figure1: Instrument of analysis of teaching practices

During the second phase the alternative planning began, guided by the following question: What kind of changes in the teaching strategies are desirable and possible? We started the Teacher Education Program (TEP) simultaneously with the preparation of new historical materials involving texts, related practical work sheets and STS questions. The TEP began with the design of the teaching strategies and materials with the required epistemological discussion. The third phase was the continuing development of the TEP that now includes the teaching of the proposed theme according to the new perspectives and finally the assessment by the participants (teachers and students) involved in the program using half-structured interviews. Only two of the initial four teachers involved wanted to participate in the 2 th and 3rd phases. The analysis of the teaching practices during the third phase was parallel to the process done in the first phase, using the analysis instrument (Fig.1). After this analysis the researchers conducted the interview step involving the critical confrontation of each teacher with selected episodes of their teaching (as revealed by videorecorded materials).

The Teacher Education Program

Given the nature of the study (collaborative action research (Elliot 1994)) the design and the implementation of the Teacher Education Program (TEP) were closely articulated.

The Teacher Education Programme (Figure 2) involved seminars, discussions and critical reflections with the collaborative organisation of the teaching strategies and the preparation of the new materials.

Meeting	Date	Place	Time	Aims and activities
Seminar	23 April 1997	University of Aveiro	8 hours	To present and discuss the interest of SH and EW as relevant dimensions to innovative science teaching strategies (Prof. J. Praia - University of Oporto) To critically explore a teaching proposal using the theme: "mass conservation in chemical reactions" at low secondary school levels (M.F. Paixão) To select participants for the subsequent phases of the study (criteria: volunteers; interested in their own education and enthusiasts; having the 8th degree in 1997/98; and who allow the videorecording of their classroom teaching). An assessment of the seminar was made by the participants (11 participants.)

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1st Individual meeting	Oct/Nov 1997	Secondary school of each participant teacher	3/4 hours	Formal contact with the head of the school To inform about the specific aims of the program. To make each one aware of the need to involve teachers in their own education with the intention of developing their own teaching practices and the subsequent empowerment of students' images of science(Action-research perspective). To discuss the importance of epistemologically based science teaching, in which the HS and EW are fundamental elements. To present the selected theme and its educational interest as a whole. To give out some documents about Philosophy of Science and Science Education as well as a document organised by researchers concerning the historical and scientific aspects of the selected theme (homework).
2nd individual meeting	Nov 1997	Secondary school of each participant teacher /teacher training college C.Branco	3/4 hours	To critically analyse and discuss the documents given out in the last meeting. To discuss the general aspects of science teaching planning. To discuss the scientific concepts involved and the students' common misconceptions. To analyse the official curriculum. To discuss the epistemological value of the theme.
3rd individual meeting	Nov 1997	//	3/4 hours	To analyse and discuss the teaching carried out during the 1st phase (videorecorded and analysed by the researchers) To begin the planning of teaching strategies
4th Individual meeting	Nov/Dec1 997	//	3/4 hours	To prepare materials: to translate texts from the original papers of Lavoisier; to prepare experimental work sheets and STS related questions. To discuss the adequacy of some materials for the development of the proposed strategies To prevent some problematic aspects. To certify that the teacher feels prepared to do the teaching of the theme in the desirable perspective
5th Individual meeting	Dec/Jan 1997/8	//	3/4 hours	During the teaching of the theme: To analyse selected videorecorded classroom episodes with the teacher. To reflect on the basis of initial goals and framework. To make eventual adjustments in the initial teaching planning and/or didactic materials To prepare a questionnaire and a half structured interview to give to the students at the end of the teaching

6th individual meeting	Feb/Marc 1998 (at the end of the sequence and after the analysis of the written protocols)	Secondary school of each participant teacher	3/4 hours	After teaching the theme: An analysis and assessment of the course (half structured interviews with each teacher): The importance and interest of the TEP. An analysis of the teaching strategy developed The interest and/or difficulties in the strategy implementation To confront the teacher with students' answers to the questionnaire and interviews. Global conclusion: To confront the teachers' analyses with the researchers' opinions and students' opinions (triangle effect)
TOTAL:7 meetings	April 97/ March 98		32 hours	

Figure 2: Teacher Education Program (TEP)

This plan was developed during half an academic year, before the 3rd phase began. In the 3 rd phase, the innovative phase, the specific aim was to reconstruct the teaching practices.

This phase was developed in a research perspective of collaborative action-research, with each participant teachers and the researchers working together systematically, namely: videorecording of all the teaching practices, with systematic feed-back on the evolution of the work, a scientific and epistemological preparation of the theme, a collaborative structuring of laboratory materials, common decisions and finally an assessment of the evolution of the program.

Results

The results are reported according to four separate aspects: The first aspect focuses on the epistemological perspectives of the teachers in the first phase, the second concernes the teachers' opinions about the TEP, the third focuses on the new epistemological aspects of the teachers' practices after and during the participation in the TEP and the final aspect highlights the relation between teachers, researchers and students' opinions.

During the first phase, the theme of mass conservation was teached basically following the same main lines by all the (4) teachers, in geographically distant schools and with different academic backgrounds. They used the same central experiment, the confrontation of mass before and after the reaction between lead nitrate and potassium iodide, and after this they induced the mass conservation law. They used this problematic-free chemical reaction between lead nitrate and potassium iodide, without reference to the existence of gaseous substances and the mass conservation in those cases. There was no discussion of and no reference to Lavoisier's time, life or work, no references to the scientific controversy that accompanied the establishment of the theory of oxygen, no references to the political, social or technological context of the building of scientific knowledge... No mention was made of particular scientific facts, terms or experiments... The image of science as a neutral body of knowledge translating a naive image of realism was prevalent. Specific epistemological aspects related to the theme were totally absent. In short, pedagogical and scientific concerns prevailed and an instrumental view of science and of the construction of scientific konwledge was passed to the students.

However, the teaching practices developed by each of the two participant teachers during the 2th and the 3rd phases reflected some suitable changes of epistemological relevance. In fact, more value was given to a more rationalist image of the role of the experiment and also to the critical role of theory and its articulation with observation. Prediction activities were introduced. Also the error was considered to play an important role in students´learning. The HS conducted the strategy and the dependence on scientific knowledge of the whole context and the related STS questions about the theme were highlighted. The naive realistic perspective about the world gave place to a more critical perspective.

The two teachers recognised the changes ocurred in their usual teaching of the topic. They were also aware of the influence of the TEP in changing their science images and their understanding of the teaching and the value of an adequate epistemological perspective of science teaching.

The teachers' confrontation with their initial own teaching is a fundamental step in order to make them aware of the kind of improvements needed. That implies an individual approach to the "intervention phase".

The teachers' opinions may be categorised in three main related aspects: the personal and professional meaning of the involvement in the developed program; the thrust of the program in their classroom practices and the analysis of their own classroom teaching as well as the access to the analysis made by the researchers.

As teacher A said: *"I really want to change... and... I will at least... change the... way... I teach this theme..."*

"The documents were interesting, it was a very good proposal... but what I considered the best during the training was effectively the dialogue between us... I felt the necessity to say and do more in the classroom... students did ask those predicted questions... I could foresee those questions... and... it was interesting."

Having access to the analysis made by researchers was considered a very important aspect: *"You referred to many aspects... I felt these things and... in a concrete way! So, I'm going... to make my teaching practice different... based on the analysis made... I'm going... to improve, no doubt about it!"*

Teacher B evaluated her participation in the TEP: *"It was very useful... all teachers should have access to some videorecorded teaching practices and reflect on them... I think they should."* And about changing her epistemological perspective *"...the experimental method... We used to say that sequence of... of phases... and now I have began to wonder also about this sequence, the meaning of what I used to say."*

The study was developed with the assumption that to improve teaching, based on an up-to-date epistemological perspective, the students' understanding about the scientific content and their images of science will increase in the same direction as well as the interest and participation in the classroom activities. The students' opinions suggest two main concerns: their understanding of the curricular theme was good and the interest in the way it was developed in the classroom was greatly appreciated. The first aspect was assessed by each teacher and also in the final interviews conducted by researchers (two different questions related to mass conservation in different situations, open and closed system). As one of teacher A's students said: *"It was a very different way of learning... It was not just arriving in the classroom and simply to speak about the subject was".... "it was not easy for him to arrive at that theory"*. Teacher B's students perceived the difficulty in changing a theory: *"It was difficult... and it took a long time for it to be accepted"*. Concerning the interest of the theme and the way it was done in the classroom this same student said: *"We were interested in what was going on in the classroom... some times this does not happen"*. Another student added: *"We also talked about these aspects outside the school, during breaks or after the chemistry class and... in fact... we talked and... we discussed those problems"*.

This arguments converge with that of the researchers, in a triangular form of internal assessment of the study, towards the acknowledgement of the interest of this new approach to teach mass conservation.

Conclusions and educational implications for science teacher education

This approach represents a significant improvement of teacher education research because it involves researchers and collaborative teachers with the same goals involved together with the central objective of effectively changing science teaching practices. Significant efforts have been made to make participant teachers aware of the effective significance of the consideration of the epistemological perspectives in teaching practices with a view to developing students' desired understanding of science and scientific knowledge (images of science).

At present we can delineate a central framework for in-service teacher education: The history and philosophy of science contribute in a sustainable way to teacher education. Effectively, when teachers are involved in an

action-research program designed with reference to a suitable selected central theme of the curricular programme their classroom practice improves in a desirable, epistemologically consistent way.

In practical terms, it is necessary to start with the selection of an interesting theme with epistemological relevance and to prepare its teaching with interested and capable teachers. The comparison with more traditional teaching (self-observation) reveals a good teacher education strategy which increases personal and professional fulfilment. The approach outlined here may be developed in other epistemologically interesting curricular areas.

There are some critical aspects, as pointed out earlier, related to difficulty in conducting these lengthy studies. This is probably why the teachers' adherence to these processes of education is still very weak.

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Keywords: teacher education; history and philosophy of science; chemistry

Financial support by FCT/Portugal

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Proceedings of X Symposium of the International Organization for Science and Technology Education (IOSTE) I + II Vols

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Corporate Source:	Publication Date:
School of Education, University of São Paulo, Brazil	July 2002

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